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(56) References cited:
EP-A- 0 102 139
WO-A-95/22169
US-A- 3 866 077

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Description

FIELD OF INVENTION

[0001] The present invention relates to lighting, and more particularly to a lighting apparatus employing a suitable phosphor in combination with a cold cathode field emitter. This invention is the result of a contract with the U.S. Department of Energy (Contract No. W-7405-ENG-36).

BACKGROUND OF THE INVENTION

[0002] Fluorescent lighting has been the standard illumination method in commercial buildings for many years. While it is used in a lessor degree in homes, it is generally applied where large areas need to be economically lighted. Although incandescent tungsten lighting is less efficient and more costly than fluorescent lighting, incandescent bulbs are the primary method of home lighting because of superior convenience and ascetics.

[0003] Although fluorescent lighting is a highly efficient method of lighting, it does suffer from several deficiencies. Among these deficiencies are ecological concerns. Fluorescent light tubes are now classified as hazardous materials by the U.S. Environmental Protection Agency (EPA) as these tubes contain mercury, a highly toxic and regulated material. This problem has lead to developments such as in U.S. Patent Nos. 5,229,686 and 5,229,687 which describe the potential leaching problems of the mercury from such lights and the addition of a chemical agent to these lights for reaction with the mercury upon pulverization of the light. Further, the ballast resistor required in most, if not all, fluorescent lighting systems can contain polychlorinated biphenyl oils (PCB'S), such materials being highly carcinogenic materials also regulated by the EPA.

[0004] Generally, the production of light in a fluorescent bulb takes several steps. First, liquid mercury within the tube is electronically heated to volatilize at least some of the mercury. Then, an electric current is passed through the mercury vapor to excite the mercury into a plasma state. The excited mercury plasma emits ultraviolet (UV) light. Finally, the UV light strikes a phosphor in the bulb with the phosphor converting the UV light energy into emitted visible light. This light production pathway has certain performance shortcomings. In comparison to conventional incandescent tungsten lighting systems, fluorescent lighting systems are slow to start as the mercury must first be heated to provide mercury vapor. Also, fluorescent lights are known to make acoustic noise due to the transformer and ballast register electronics needed to start and keep the current flowing through the mercury vapor. Oscillation in light output from fluorescent lighting can occur when the system is cold and first turned on thereby distracting some people. Further, fluorescent lighting systems are typically incompatible with conventional dimming technology used to adjust the light brightness output necessitating expensive dimmable fluorescent lighting using more exotic electronics.

[0005] I. Brodie, U.S. 4,818,914, discloses a lamp comprising a cathode formed with an array of needle-like members projecting from one surface thereof, an accelerator electrode formed with an array of apertures there through, a layer of phosphor and an anode electrode. Voltages applied across the cathode and the accelerator electrode and across the cathode and the anode result in field emission from the cathode and collection of the electrons by the anode. Impingement of the electrons on the phosphor layer results in the emission of light. Dworsky et al., U.S. 5,180,951, discloses a uniform light source comprised of a substantially planar (flat) polycrystalline diamond film electron emitter. Y. Taniguichi et al., WO 94/28571, disclose a fluorescent tube light source comprising a layer of amorphic diamond film deposited over a conductive filament and an anode surrounding this filament and film which radiates light when struck by the emitted electrons. The amorphic diamond film is said to be comprised of a plurality of distributed localized electron emission sites, each sub-site having a plurality of subregions with differing electron affinities between sub-regions.

[0006] US-A-3 866 077 discloses a carbon filament used for the emission of electrons from the tip or end of the constituent carbon fibres. EP-A-0 102 139 discloses cathodoluminescent light sources and electrical lighting arrangements including such sources.

[0007] It is an object of the present invention to provide a mercury-free fluorescent light employing a fibrous field emission element.

[0008] It is another object of the present invention to provide a fluorescent light having a substantially instant turn-on.

[0009] Still another object of the present invention is to provide a low voltage, low power backlight.

SUMMARY OF THE INVENTIONS

[0010] To achieve the foregoing and other objects, and in accordance with the purposes of the present invention, as embodied and broadly described herein, the present invention provides a lighting apparatus including a fibrous cold cathode field emitter wherein fibers of said cold cathode have a diameter of less than 100 microns, an anode for reaction of electrons emitted by the fibrous cold cathode field emitter, a phosphor capable upon contact with emitted electrons from the cold cathode field emitter of generating a persistent light, an evacuated enclosure of less than $133{,}3 \cdot 10^{-5}$ Pa (10^{-5} Torr) containing within the enclosure the cold cathode field emitter, the anode and the phosphor. The persistent light preferably has a luminous intensity of at least 20 lumens per watt.

[0011] The dependent claims set out particular embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

[0012] FIGURE 1 shows an elongated tube device in accordance with the lighting apparatus of the present invention.

[0013] FIGURE 2 shows an exploded view of a flat plate device in accordance with the lighting apparatus of the present invention.

[0014] FIGURE 3 shows a bulb device in accordance with the lighting apparatus of the present invention.

[0015] FIGURE 4 shows a light beam producing device in accordance with the lighting apparatus of the present invention.

[0016] FIGURE 5 shows a test device in accordance with the lighting apparatus of the present invention.

[0017] FIGURE 6 shows driver circuits for the lighting device of the present invention.

[0018] FIGURE 7 shows a bulb device for use in standard light bulb sockets.

DETAILED DESCRIPTION

[0019] The present invention relates to a field emission lighting apparatus and to a fiber field emission lighting (FFEL) apparatus.

[0020] The lighting apparatus of the present invention uses field emission to generate light output from a phosphor, e.g., a cathodoluminescent material.

[0021] The field emission lighting apparatus involves a fibrous cold cathode field emitter. The field emission electron emitting material can be any material that can be provided in the form of a fiber. Preferably the field emission electron emitting material of the fibrous cathode is diamond, diamond-like carbon or glassy carbon. Diamond is especially preferred. Preferably the fibrous cathode is formed of one or more diamond, diamond-like carbon or glassy carbon composite fibers consisting essentially of diamond, diamond-like carbon or glassy carbon on non-diamond core fibers. The non-diamond core can be made of a conductive or semi-conductive material. Alternatively, the core can be made of a non-conductive material surrounded by a film coating of a conductive or semi-conductive material. The core material in the diamond fiber can be, e.g., a conductive carbon such as graphite or a me al such as tungsten, or can be, e.g., silicon, copper, molybdenum, titanium or silicon carbide. In another embodiment, the core may consist of a more complex structure, for example. a non-conductive material surrounded by a thin coating of conductive or semi-conductive material. A diamond, diamond-like or glassy carbon layer is then coated on the sheath. As examples, the non-conductive core can be a synthetic fiber such as nylon, KEVLAR® (KEVLAR® is a registered trademark of E. I. du Pont de Nemours and Company, Wilmington, DE), or polyester or inorganic materials such as ceramics or glass. In other embodiments, a diamond, diamond-like carbon or glassy carbon precursor can be coated onto the non-diamond core or the core can be a diamond, diamond-like carbon or glassy carbon precursor and the diamond, diamond-like carbon or glassy carbon is then formed by appropriate treatment of the precursor.

[0022] In particular, the field emission lighting apparatus involves a fibrous cold cathode field emitter which can be of the type described by Valone, in US-A-5 602 439 (U.S. patent application serial number 08/196,343, filed February 14, 1994,) entitled "DiamondGraphite Field Emitters" or by Blanchet-Fincher et al., in US-A-5 570 901 (U.S. patent application serial number 08/387,539, filed February 13, 1995), entitled "Diamond Fiber Field Emitters" which is a continuation-in-part of Valone et al., U.S. patent application serial number 08/196,340, filed February 14, 1994, entitled "Diamond Fiber Field Emitters." Further, the cold cathode field emitter can be any other suitable emitting fibrous material such as a suitable graphite fiber treated by exposure to intense ion beam treatment or a suitable graphite fiber treated by exposure to a laser as described by Friedmann, in U.S. provisional patent application number 60/002,277, entitled "Method for Creation of Controlled Field Emission Sites" filed August 14, 1995, or a diamond-coated or diamond-like-coated nickel-coated KEVLAR® fiber as described in US-A-5 578 901 (U.S. patent application number 08/387,539, filed February 13, 1995), or fibers containing glassy carbon, an amorphous material exhibiting Raman peaks at about 1380 cm^{-1} and 1598 cm^{-1} "Diamond-like carbon" is used herein to designate the material referred to in the literature as diamond-like carbon as well as glassy carbon and carbon containing microscopic inclusions of glassy carbon, all of which are diamond-like in their performance as field emission materials.

[0023] Additionally, the fibrous cold cathode may generally be of an conductive material having an activated surface, i.e., capable of allowing electrons to be drawn off at a relatively low bias voltage, with suitable dimensions, i.e., diameters of generally less than 100 μm (microns), preferably less than 15 μm (microns), and more preferably less than 10 μm (microns). Among the suitable materials may be included thin fibers of magnesium oxide and the like, suitably with an activated surface based on treatment of the fibers by, e.g., flash heating.

[0024] Generally, the fibers of the fibrous cathode each have diameter of less than 100 μm (microns), preferably less than 15 μm (microns), and more preferably less than 10 μm (micron). Smaller diameter fibers reduce the voltage necessary to generate the field emission. Preferably, the diameter exceeds 1 μm (micron). Generally, diameters of the fibers of the cold cathodes are substantially smaller in dimensions than the metallic filaments commonly used in presently available lighting apparatus. While a single fiber can be used as the fibrous cathode, it is generally preferred to use more than a single fiber as the fibrous cathode to provide redundancy in electron emission.

[0025] The phosphor used in the lighting apparatus of

the present invention can generally be of any type suitable to generate visible light upon being struck by electron emission. For example, the phosphor can be zinc oxide:zinc, zinc sulfide, cadmium sulfide, zinc cadmium sulfide, zinc selenide, zinc cadmium selenide yittrium silicate:cesium, zinc phosphate:maganese, or other well known materials which emit light following suitable excitation. Blends or combinations of phosphors may also be employed.

[0026] The phosphor used in the present invention is further capable of producing a persistent light, i.e., the light from a particular point of the phosphor does not readily fade with time as it is excited. Additionally, the output from the excited phosphor may be capable of generating this persistent visible light with a luminous intensity of at least 20 lumens per watt.

[0027] The lighting apparatus of the present invention includes a fibrous cold cathode field emitter, a phosphor, an anode for attraction of emitted electrons from the cold cathode field emitter, all generally contained within an evacuated enclosure. Unlike a standard mercury vapor fluorescent light, the lighting apparatus of the present invention can turn on instantly without the need for heating the mercury to form a plasma. Without the need for maintaining a plasma, the light generated by the lighting apparatus of the present invention can be readily and easily dimmed or brightened by adjustment of the voltage applied to the fiber. When more voltage is applied, more electrons are emitted and impinge upon the phosphor material resulting in additional light output, i.e., a brighter light. When less voltage is applied, but above the minimum turn-on voltage for the fibrous field emitter, less electrons are emitted and impinge upon the phosphor material resulting in a reduction in light output, i.e., a dimmer light. No starting circuits are necessary for the lighting apparatus of the present invention, only a rectifying voltage step-up circuit and a simple current limiting circuit. Such a current limiting circuit can consist, e.g., of a small resistor/inductor in series with the fibrous cold cathode.

[0028] The evacuated enclosure typically maintains a low pressure of least as low as $133{,}3 \cdot 10^{-5}$ Pa (10^{-5} Torr). Such an evacuated enclosure can be, e.g., a glass bulb or multiple glass sheets with appropriate spacer material therebetween.

[0029] The lighting apparatus of the present invention uses electron emission induced by a directed, shapable applied field. This is in contrast with lighting using a plasma which results in a non-directed light source. This allows practical, but varied, shape configurations of the present lighting apparatus without limitations to the traditional elongated tube. No matter what shape the lighting apparatus has, electron emission from the fibers of the fibrous cathode occurs along the length of the fibers utilized and not from the fiber tip or end.

[0030] In one embodiment of the present invention, shown in Fig. 1, a light 10 included a glass tube 12 as an evacuable enclosure. The inner or interior surface of glass tube 12 can be coated with a transparent conductor as an anode and a phosphor or cathodoluminescent material 13. A fibrous cathode element 14, the fibrous field emitter, is situated within glass tube 12. An end cap 16 includes electrodes connected to fibrous cathode element 14 and to the transparent conductor coating or anode. The fibrous cathode element can consist of a single fiber, can include a multiple of fibers or can include a thicker single fiber. Generally, the single fiber or individual fibers making up the multiple fibers can have a diameter of from 1 micron to 20 microns, preferably 5 microns to 10 microns. The glass tube can be a circular cylinder as shown or it can have a configured surface.

[0031] In another embodiment of the present invention, shown in Fig. 2, light 20 has a flat plate design with a flat plate 22 having a fibrous cathode element array 24 thereon. A transparent second flat plate 26 includes a coating of transparent conductor 28 upon the surface of flat plate 26 facing cathode element array 24 and a coating of a phosphor or cathodoluminescent material 30 upon transparent conductor coating 28. A spacer plate 32 separates flat plate 22 and flat plate 26 and provides an evacuable enclosure for fibrous cathode element array 24, transparent conductor coating 28 and phosphor or cathodoluminescent material 30. Conductor electrodes are connected to transparent conductor coating 28 and fibrous cathode element array 24.

[0032] In another embodiment of the present invention, shown in Fig. 3, a bulb-shaped light 40 includes a glass globe 42 having an interior coating of a transparent conductor 44 and a coating of a phosphor or cathodoluminescent material 46. A fibrous cathode element 48, the fibrous field emitter, is situated within glass globe 42. Conductors are connected to fibrous cathode element 48 and to the transparent conductor coating or anode 44. The fibrous cathode element 48 can consist of a single fiber or can include a multiple of fibers. Generally, the single fiber or individual fibers making up the multiple fibers can have a diameter of from 1 μm (micron) to 20 microns, preferably 5 μm (microns) to 10 μm (microns).

[0033] In another embodiment of the present invention, shown in Fig. 4(a) and Fig. 4(b), a light 50 capable of producing a light beam output 52 includes glass hemispherical support 54 having coatings upon the concave inner surface of a reflector material 56, a transparent conductive material 58, and a phosphor or cathodoluminescent material 60. A fibrous cathode element 62, the fibrous field emitter, is situated within glass hemisphere 54. Conductors are connected to fibrous cathode element 62 and to the transparent conductor coating or anode 58. Varying the shape of the glass suppon 54 can result in a more concentrated light beam. For example, a parabolic support would accomplish this result.

[0034] Figure 5 shows a simple test device used to test field emission variables of the fibrous cathodes including a clear plastic, e.g., Lucite® plastic, tube 70

capped with end caps 72 and 74 to form an evacuable enclosure. End cap 72 includes an opening 76 connected to a vacuum pump. Suspended within the evacuable enclosure is a grounded copper screen mesh 78 coated with a phosphor or cathodoluminescent material 80. A fibrous cathode element 82 is situated within grounded copper screen mesh 78. Conductors are connected to fibrous cathode element 82 and to copper screen mesh or anode 78. This test device can prove useful for determining emission uniformity of emissive fibers.

[0035] Figure 6 shows a current limiting circuit for use with the lighting apparatus of the present invention. The current limiting circuit 90 includes resistor 92 and an inductor 94 in series with the emissive fiber or fibrous cathode element 96. Power source 98 is connected through a rectifying voltage step-up circuit 100 to the anode 102 and the current limiting circuit 90 in series with cathode element 96.

[0036] In another embodiment of the present invention, shown in Fig. 7, light 120 is in the form of a standard light bulb with a screw type base. The inner surface of the glass bulb 121 is coated with a transparent conducting oxide 122 and a phosphor or cathodoluminescent material 123. A fibrous cathode field emitter comprised of a field emission electron emitting fiber 124 is in the central region of the bulb. The fiber emitter is shown in a triangular configuration but could be in other configurations, e.g., a circle or a figure having four or more sides. The fiber emitter is supported by a non-emitting current carrier 125. Emitted electrons are shown by the arrows 126. The screw type base 127 is essentially the same as used for standard incandescent bulbs.

[0037] In operation of the lighting apparatus of the present invention, power density of about 1.5 watts per inch (1 inch = 2,54 cm) from the cathode can generally be necessary to generate sufficient electron emission. Generally, if the bias voltage on the fibrous cathode is at least 1500 Volts, then the emission current per inch (1 inch = 2,54 cm) must be at least 1 milliamperes.

[0038] The present invention is more particularly described in the following example which is intended as illustrative only.

EXAMPLE 1

[0039] A lighting apparatus was assembled essentially as shown in Figure 5 using a carbon fiber that was exposed to a single intense ion beam treatment. The carbon fiber was prepared as follows.

[0040] Untreated graphite fibers (commercially available IM7 graphite fibers from Hercules, Inc., Wilmington, DE) from a graphite yarn were spread out across a frame and the frame placed in the path of an intense ion beam operated in accordance with the teachings of Rej et al., Rev. Sci. Instrum. 64(10), pp. 2753-2760, Oct. 1993. The voltage was about 300 kilovolts. The distance of the frame from the focus of the ion beam was varied between 15 cm (six inches) to 45 cm (18 inches). The energy density of the ion beam was estimated at from 2 joules per square centimeter to 10 joules per square centimeter. The time of a pulse of the ion beam was about one microsecond. After a single pulse, the frame was turned over (180°) and the reverse side of the fibers was exposed to a single pulse of the intense ion beam. The resultant fibers were tested and shown to be excellent field emission electron emitters.

[0041] A fiber was then attached to conductor "A" shown in Figure 5. A zinc oxide:zinc phosphor was coated onto the copper mesh screen. A potential difference of about 3.5 keV was applied to the cathode and anode, i.e., to conductors "A" and "B". A current of 2-3 mA was obtained over a one inch (2.5 cm) length of fiber together with a persistent light emission. About 10 watts per inch (2.5 cm) was obtained for lighting purposes.

[0042] Although the present invention has been described with reference to specific details, it is not intended that such details should be regarded as limitations upon the scope of the invention, except as and to the extent that they are included in the accompanying claims.

Claims

1. A lighting apparatus (10, 20, 40, 50) comprising:

    a fibrous cold cathode field emitter (14, 24, 48, 62) including one or more fibers, said one or more fibers of said fibrous cold cathode having a diameter of less than 100 microns;
    an anode (28, 44, 58) for attraction of electrons emitted by the fibrous cold cathode field emitter;
    a phosphor (13, 30, 46, 60) capable upon contact with emitted electrons from the fibrous cold cathode field emitter of generating persistent light;
    an evacuated enclosure (12; 22, 26, 32; 42; 54) of less than 10^{-5} Torr containing within the enclosure, the fibrous cold cathode field emitter, the anode and the phosphor, with the proviso that electron emission from the fibers of the fibrous cathode occurs along the length of the fibers utilized and not from the fiber tip or end.

2. The lighting apparatus of Claim 1 wherein said one or more fibers have diameters of from 1 micron to 15 microns.

3. The lighting apparatus of Claim 1 wherein said fibrous cold cathode field eminer includes more than one fiber.

4. The lighting apparatus of Claim 3 wherein said fibers have diameters of from 1 micron to 15 microns.

5. Tne lighting apparatus of Ciaim i wherein said evacuated enclosure is of a globe shape (42).

6. The lighting apparatus of Claim 1 wherein said evacuated enclosure is of a hemispherical shape (54).

7. The lighting apparatus of Claim 3 wherein said evacuated enclosure is of a globe shape (42).

8. The lighting apparatus of Claim 3 wherein said evacuated enclosure is of a hemispherical shape (54).

9. The lighting apparatus of Claim 1 wherein said evacuated enclosure is of a flat plate shape (22, 26, 32).

10. The lighting apparatus of Claim 3 wherein said evacuated enclosure is of a flat plate shape (22, 26, 32).

11. The lighting apparatus of Claim 1 wherein said evacuated enclosure is of a cylindrical shape (12).

12. The lighting apparatus of Claim 3 wherein said evacuated enclosure is of a cylindrical shape (12).

13. The lighting apparatus of Claim 1 wherein said apparatus is further characterized as mercury-free.

Patentansprüche

1. Beleuchtungsvorrichtung (10, 20, 40, 50), die aufweist:

   einen faserförmigen Kaltkathoden-Feldemitter (14, 24, 48, 62) mit einer oder mehreren Fasern, wobei die eine oder die mehreren Fasern des faserförmigen Kaltkathoden-Feldemitters einen Durchmesser von weniger als 100 µm aufweisen;
   eine Anode (28, 44, 58) zum Anziehen von Elektronen, die durch den faserförmigen Kaltkathoden-Feldemitter emittiert werden:
   einen Leuchtstoff (13, 30, 46, 60), der bei Kontakt mit von dem faserförmigen Kaltkathoden-Feldemitter emittierten Elektronen Dauerlicht erzeugen kann;
   ein evakuiertes Gehäuse (12; 22, 26, 32; 42; 54) mit einem Druck von weniger als 10^{-5} Torr, das innerhalb des Gehäuses den faserförmigen Kaltkathoden-Feldemitter, die Anode und den Leuchtstoff enthält, unter der Voraussetzung, daß die Elektronenemission von den Fasern der faserförmigen Kathode längs den verwendeten Fasern und nicht von der Faserspitze oder vom Faserende erfolgt.

2. Beleuchtungsvorrichtung nach Anspruch 1, wobei die eine oder die mehreren Fasern Durchmesser von 1 µm bis 15 µm aufweisen.

3. Beleuchtungsvorrichtung nach Anspruch 1, wobei der faserförmige Kaltkathoden-Feldemitter mehr als eine Faser aufweist.

4. Beleuchtungsvorrichtung nach Anspruch 3, wobei die Fasern Durchmesser von 1 µm bis 15 µm aufweisen.

5. Beleuchtungsvorrichtung nach Anspruch 1, wobei das evakuierte Gehäuse eine Kugelform (42) aufweist.

6. Beleuchtungsvorrichtung nach Anspruch 1, wobei das evakuierte Gehäuse eine Halbkugelform (54) aufweist.

7. Beleuchtungsvorrichtung nach Anspruch 3, wobei das evakuierte Gehäuse eine Kugelform (42) aufweist.

8. Beleuchtungsvorrichtung nach Anspruch 3, wobei das evakuierte Gehäuse eine Halbkugel form (54) aufweist.

9. Beleuchtungsvorrichtung nach Anspruch 1, wobei das evakuierte Gehäuse eine flache Plattenform (22, 26, 32) aufweist.

10. Beleuchtungsvorrichtung nach Anspruch 3, wobei das evakuierte Gehäuse eine flache Plattenform (22, 26, 32) aufweist.

11. Beleuchtungsvorrichtung nach Anspruch 1, wobei das evakuierte Gehäuse eine zylindrische Form (12) aufweist.

12. Beleuchtungsvorrichtung nach Anspruch 3, wobei das evakuierte Gehäuse eine zylindrische Form (12) aufweist.

13. Beleuchtungsvorrichtung nach Anspruch 1, wobei die Vorrichtung ferner als quecksilberfrei charakterisiert ist.

Revendications

1. Appareil d'éclairage (10, 20, 40, 50) comprenant:

   un émetteur de champ à cathode froide à fibres (14, 24, 48, 62) incluant une ou plusieurs fibres, lesdites une ou plusieurs fibres de ladite catho-

de froide à fibres présentant un diamètre inférieur à 100 micromètres;
une anode (28, 44, 58) pour l'attraction d'électrons émis par l'émetteur de champ à cathode froide à fibres;
un phosphore (13, 30, 46, 60) qui, suite à un contact avec des électrons émis depuis l'émetteur de champ à cathode froide à fibres, peut générer une lumière persistante;
une enceinte sous vide (12; 22, 26, 32; 42; 54) à moins de 10^{-5} Torr contenant, à l'intérieur de l'enceinte, l'émetteur de champ à cathode froide à fibres, l'anode et le phosphore, étant entendu qu'une émission d'électrons depuis les fibres de la cathode à fibres se produit suivant la longueur des fibres utilisées et non pas depuis la pointe ou extrémité des fibres.

2. Appareil d'éclairage selon la revendication 1, dans lequel lesdites une ou plusieurs fibres présentent des diamètres de 1 micromètre à 15 micromètres.

3. Appareil d'éclairage selon la revendication 1, dans lequel ledit émetteur de champ à cathode froide à fibres inclut plus d'une fibre.

4. Appareil d'éclairage selon la revendication 3, dans lequel lesdites fibres présentent des diamètres de 1 micromètre à 15 micromètres.

5. Appareil d'éclairage selon la revendication 1, dans lequel ladite enceinte sous vide présente la forme d'un globe (42).

6. Appareil d'éclairage selon la revendication 1, dans lequel ladite enceinte sous vide présente la forme d'un hémisphère (54).

7. Appareil d'éclairage selon la revendication 3, dans lequel ladite enceinte sous vide présente la forme d'un globe (42).

8. Appareil d'éclairage selon la revendication 3, dans lequel ladite enceinte sous vide présente la forme d'un hémisphère (54).

9. Appareil d'éclairage selon la revendication 1, dans lequel ladite enceinte sous vide présente la forme d'une plaque plane (22, 26, 32).

10. Appareil d'éclairage selon la revendication 3, dans lequel ladite enceinte sous vide présente la forme d'une plaque plane (22, 26, 32).

11. Appareil d'éclairage selon la revendication 1, dans lequel ladite enceinte sous vide présente la forme d'un cylindre (12).

12. Appareil d'éclairage selon la revendication 3, dans lequel ladite enceinte sous vide présente la forme d'un cylindre (12).

13. Appareil d'éclairage selon la revendication 1, dans lequel ledit appareil est en outre caractérisé comme étant exempt de mercure.

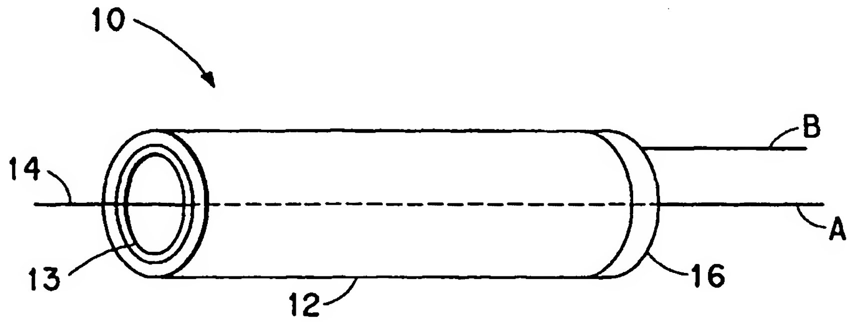

FIG.1

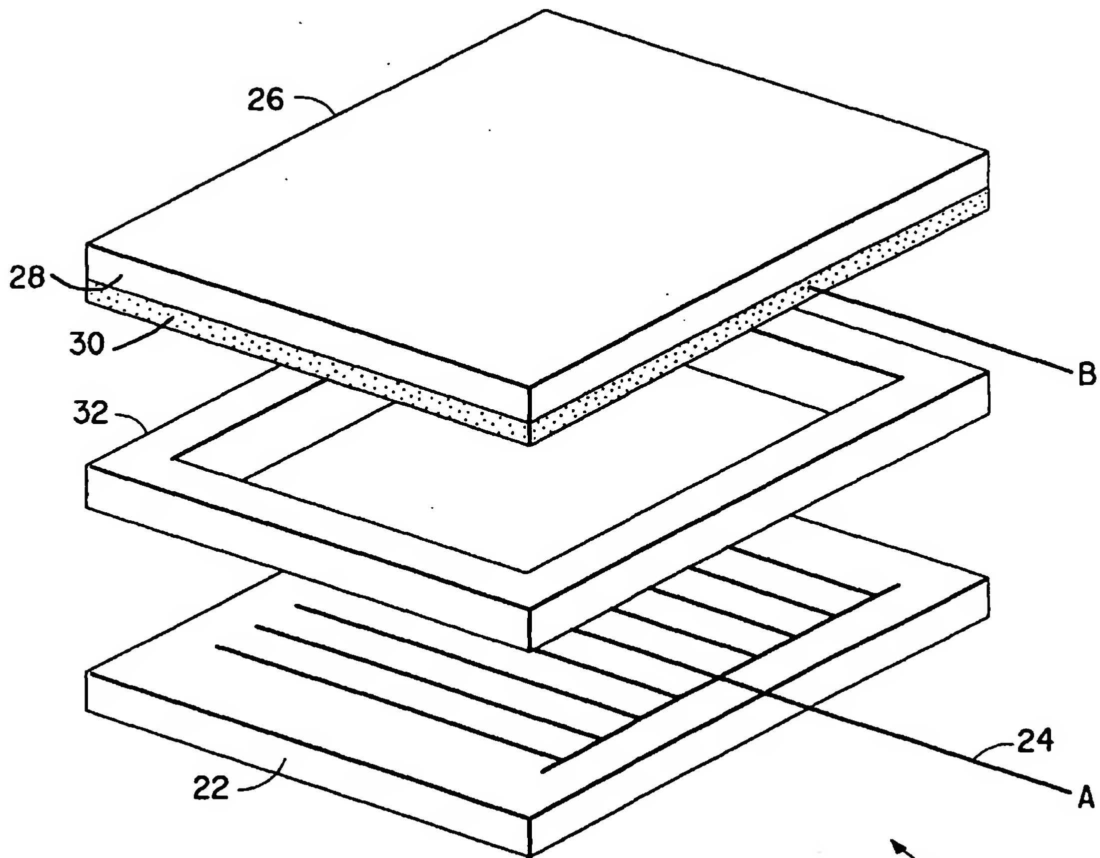

FIG.2

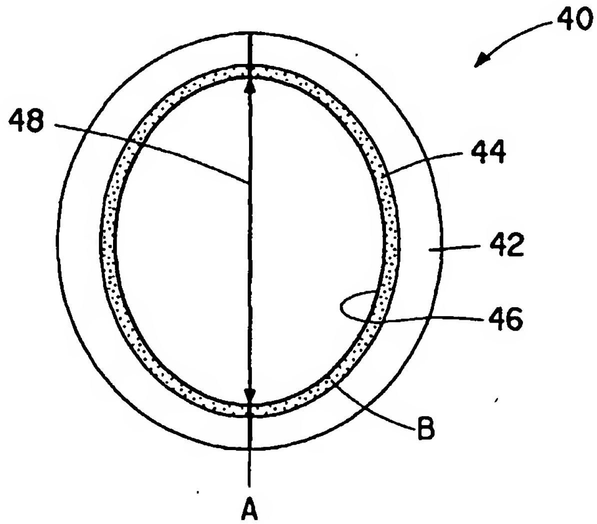

FIG.3

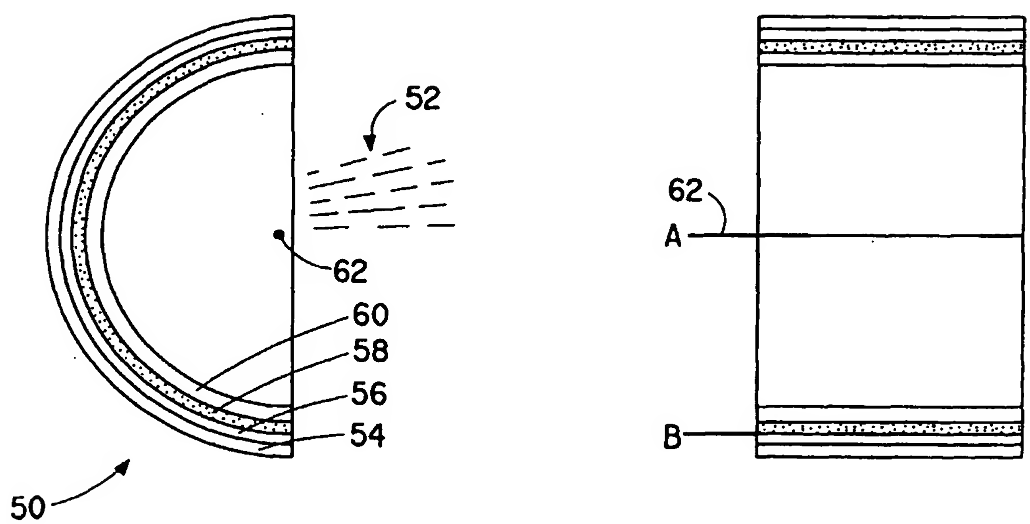

FIG.4A FIG.4B

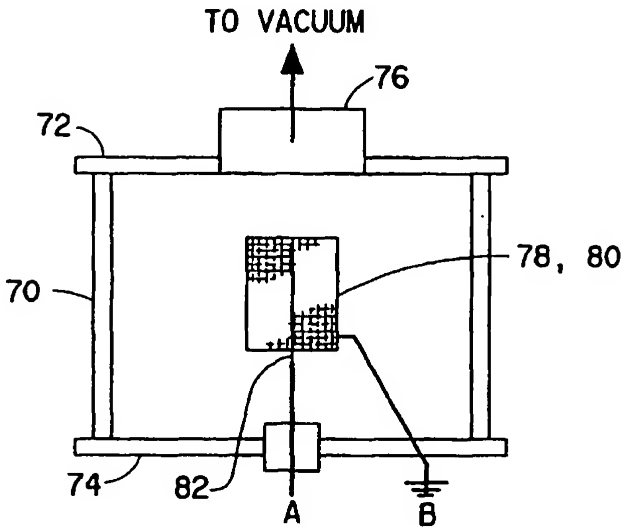

FIG.5

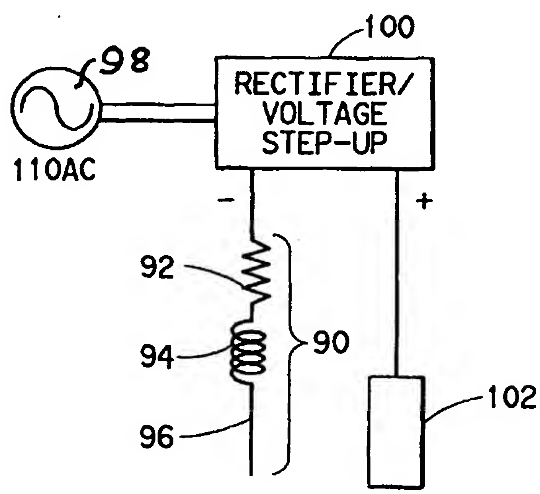

FIG.6

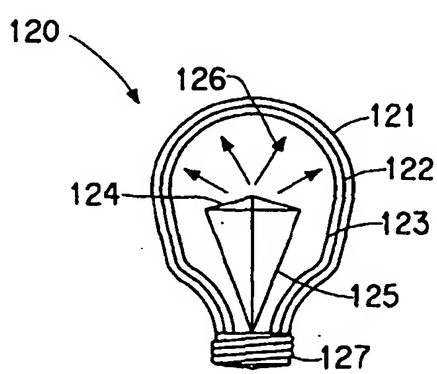

FIG.7